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A SUCCESSFUL DIRECT SEEDING of SUGAR PINE

RESEARCH PAPER NO. 25

by

William I. Stein

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SUMMARY

In southwestern Oregon, the first pilot-scale direct seeding of sugar pine produced a well-stocked stand of seedlings on a 45-acre tract. Control of seed-eating rodents was accomplished by spot-baiting with 1080-treated wheat before seeding, by spot-baiting with thallium sulfate-treated wheat in late December, and by broadcast-baiting with 1080-treated wheat in early May. In November, seed was placed in the ground less than an inch deep in spots spaced 4 x 8 feet apart. Seeding and poisoning combined required approximately one man-day per seeded acre.

Detailed results concerning germination and survival were obtained for marked seedspots. One-third of the spots sown alternately with one and two seeds each were stocked at the end of the second year. Almost 60 percent of a limited number of spots that received two seeds each were stocked. Only 34 percent of all seedlings died within the first two years; insects and rodents caused 62 percent of the mortality. A survey showed 72 percent stocking and 455 seedlings per acre at the end of the second year.

Some leads were found for improving seedspotting. Comparisons of germination and survival for several classes of ground surface, seedbed composition, and vegetative cover demonstrated that both germination and survival were generally better on exposed mineral soil free of debris and vegetation. Surfaces blackened when burning logging debris, and rock-soil surfaces proved to be average or better seedbeds. A small spring trial demonstrated that stratified sugar pine germinates slowly, and that spring-sown seed needs careful protection from rodents.

A preliminary guide is presented for choosing the combination of spacing interval and seeds per spot necessary to obtain a given density of two-year-old seedlings.

Research Paper 25

A SUCCESSFUL

DIRECT SEEDING OF SUGAR PINE

by

William I. Stein

Siskiyou-Cascade Research Center

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Sugar pine (Pinus lambertiana Dougl.) commands a prominent position in forest management plans for parts of southwestern Oregon and northern California. Its regeneration is desired on many cutovers; but for good natural reproduction, seed crops are too intermittent, and sufficient seed trees are often not available. Accordingly, direct seeding methods have been tried in a continuing series of tests. Results from the first large-scale test, conducted jointly with the Umpqua National Forest, are reported in this paper. A good stand of sugar pine seedlings was obtained.

METHODS

The Study Area

The pilot-scale seeding was made on 45 acres of a 67-acre clearcut on Zinc Creek in the upper South Umpqua drainage, 18 miles east of Tiller, Oreg. Elevations range from 2,950 to 3,300 feet. All aspects are represented on the area with southwest, northwest, and north predominating. The soil is a friable, brown clay loam with a dense "B" horizon.

The original dense mixed stand of Douglas-fir, sugar pine, grand fir, and incense cedar was tractor-logged in 1951, and slash was burned in the fall of 1952 shortly before seeding. The burn was medium to heavy (fig. 1) but some slash in heavily vegetated locations along the shaded south edge remained unburned.

Rodent Control

Widespread experience throughout the Northwest has well demonstrated that protection of seed from rodents is essential for the success of most direct seedings. Efforts to protect seed by reducing the rodent population with poison bait have met with varying degrees of success. However, previous efforts usually depended on a single application of bait to achieve adequate control. In this study, efforts were intensified. Periodic checks were made to determine rodent presence and activity, and the area was baited three times to minimize seed and seedling losses.

Figure 1.--A view of the seeded area looking southeast from the north boundary. Slash was thoroughly burned in most places.

The first baiting, done in late November before seeding, almost eliminated the light initial rodent population. From 10 to 20 kernels of wheat treated with sodium fluoroacetate (1080) were placed in sheltered spots located approximately 25 by 50 feet apart. A 200-foot buffer strip surrounding the clearcut was baited with spots about 25 by 25 feet apart. Baiting reduced the number of traps disturbed by rodents from 13 to 1 percent per night, but disturbance of one trap and the sighting of a squirrel and a chipmunk along one edge indicated that after treatment the area was not entirely free of rodents.

The second poisoning in late December was precautionary. More than a foot of snow covered the ground and it was feared that further snow would make the seeded area inaccessible for the next three months. Consequently, poison was distributed a second time to keep the rodent population down during the winter. Wheat treated with thallium sulfate was placed in spots 50 feet apart over the seeded area and a 50-foot-wide buffer strip. Because of snow depth, bait was placed only in sheltered, snow-free locations and no rodent census was made.

In February and March, after warm rains had melted away the snow, two one-night trapping censuses and examinations of staked seedspots revealed little rodent activity. However, during April rodents dug up many stratified seeds that had been spotted on two acres of the clearcut in a small spring trial.[1/] Consequently, a third poisoning was made May 11. Wheat treated with 1080 was broadcast on the seeded area, but no buffer strip was baited.

Seeding

The seeding techniques tried in this study were based on earlier observations and small-scale experiments. Previous tests[2/] had demonstrated that stocking might be expected in about half the spots sown. Therefore, a spacing of 4 x 8 feet between seedspots, with two seeds sown not over an inch deep in each spot, appeared reasonable to attain very adequate stocking. If seedlings were established in half the spots, the seeding would be as successful as 100-percent survival in planting with 8 x 8 spacing.

However, when seeding was begun immediately after the first baiting, it soon became evident that there wasn't enough seed to sow two seeds per spot over the entire 45-acre area. Therefore, the remainder of the tract was sown with one and two seeds in alternate spots.

Three devices tried proved satisfactory for getting seed into the ground. The first was a simple dibble stick. The seeds were placed in shallow holes that were punched in the ground with the stick. The second device consisted of a 3/4-inch iron pipe approximately 4 feet long with the lower end cut on a 45-degree bevel. A short swing of the pipe created a shallow scratch or groove wherein the seed was deposited by dropping it down the pipe. Clogging of the

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1/ It has been noted in several studies that mice attack spring-sown seeds much more vigorously than fall-sown. Seed placed well under the surface in the fall, when surface foods are plentiful, have gone through the winter undisturbed, but heavy losses have been suffered during germination. Spring poisoning is considered very important.

2/ Stein, William I. Some lessons in artificial regeneration from southwestern Oregon. Northwest Science 29(1): 10-22, illus. 1955.

pipe was largely avoided by striking the ground with the closed side of the beveled point. The third device was constructed of two pieces of angle iron that were joined to permit the upward movement of one piece after the beveled point had been inserted in the ground. Seed was also dropped down this seeder and was deposited in the soil when the one side was raised. This device worked satisfactorily with one seed at a time but clogged with two. Seeds were hand-fed for all devices from a small bag carried at the waist. Each seedspot was covered by a light scufflike tread with the foot.

Labor and Materials

Seeding and poisoning combined required approximately one man-day per seeded acre (table 1). Three poisonings required a total of 18 man-days, and seeding required 28 man-days. Under favorable weather conditions, the seeding crew averaged 2 acres per man-day. Only half this rate was possible in shaded areas where the soil was frozen. Direct costs--including labor, transportation, and seed and bait--totaled approximately $18 per seeded acre.

RESULTS

Progress of the seeding was followed closely by repeated observations of staked seedspots. Two lines of about 100 spots each were staked to represent the general seeding where one and two seeds per spot were alternated. Line 1 paralleled the timber's edge 1 chain in from the north boundary, and line 2 was similarly located along the south boundary. Two additional lines (3 and 4) were staked on a 1-acre area in the center of the clearcut, where two seeds were placed in each spot. To provide comparison, a single line (5) containing spots with two seeds each was seeded on a nearby unbaited clearcut. The data collected provide detailed evidence of the fate of individual seedlings over a 2-year period.

Germination

Seedlings appeared in 56.2 percent of all spots sown alternately with one and two seeds each (table 2). Spots in which germination occurred (initial stocking) averaged 1.34 seedlings each. Seedlings appeared in 74.5 percent of the spots that received two seeds each and initial stocking averaged 1.60 seedlings per spot. Germination was poorer on the shaded, poorly burned southern edge of the clearcut than elsewhere, and better than average in the center of the clearcut. Calculated in terms of total number of seeds sown in the

Table 1.--Time and materials required for baiting and seeding

Item	Time	Approximate area	Materials		
			Kind	Amount per acre	Treatment
	Man-days	Acres		Pounds	
Rodent control					
First baiting	7	95	wheat bait	1/2	Sodium fluoroacetate
Second baiting	7	70	wheat bait	1/4	Thallium sulfate
Third baiting	4	50	wheat bait	1/2	Sodium fluoroacetate
Seeding	28	45	S. Pine seed	1	None
Total	46	--	--	--	--

Table 2.--Germination and second-year survival of direct-seeded sugar pine

Line	Seeds per spot[1]	Total seed-spots	Germination: Initial stocking[2]	Germination: Seedlings per spot[3]	2nd-year survival: Spots stocked	2nd-year survival: Seedlings alive
	Number	Number	Percent	Number	Percent	Percent
Baited:						
1	1 & 2	100.0	65.0	1.23	36.0	53.8
2	1 & 2	101.0	47.5	1.48	30.7	64.8
Average	1 & 2	100.5	56.2	1.34	33.3	58.9
3	2	100.0	75.0	1.56	56.0	70.9
4	2	100.0	74.0	1.65	61.0	76.2
Average	2	100.0	74.5	1.60	58.5	73.6
Unbaited:						
5	2	100.0	72.0	1.62	43.0	58.1

1/ Lines 1 and 2 were established near the north and south boundaries of the clearcut where spots were sown alternately with one and two seeds each. Lines 3 and 4, with two seeds per spot, were established in the center of the seeding.

2/ Spots in which seedlings appeared aboveground.

3/ Average number of seedlings in initially stocked spots.

lines, 59.8 percent of the seeds produced germinants in the center of the clearcut compared with 50.2 percent 1 chain from the timber boundary.

Since trapping censuses and examination of staked seedspots before germination are inexact means of evaluating how much rodents are actually damaging a direct seeding, germinated seedlings offer the best proof of baiting effectiveness. In this study, comparisons between results in lines 3 and 4 of the baited area and those of the 100 comparable spots in line 5 on the unbaited area demonstrate the effect of baiting.

Germination occurred in 74.5 percent of the seedspots on the baited area and in 72.0 percent of the seedspots on the unbaited area, which indicates that seed losses prior to germination were about equal. However, during germination rodents clipped 11.1 percent of the seedlings on the unbaited area and only 3.3 percent on the baited area. The difference in damage appears attributable to protection provided by eliminating rodents with poisoned bait. It is not possible to segregate the effect of spring baiting from the cumulative effect of fall and winter baiting, but it is believed that the spring baiting was the most important in giving protection during germination.

Germination failures in seedspots were caused by rodents, hollow and rotten seed, and arrested germination (table 3). All failed spots in lines 3, 4, and 5 were carefully dug up to determine the reason for failure. Of the seeds that failed to germinate in these 79 spots, over 30 percent were missing because of rodents tunneling underground (mainly gophers), and nearly 4 percent were missing because of rodent activity aboveground. Rodent-caused seed loss was judged less in unbaited line 5 than in baited lines 3 and 4. Only a few seeds were hollow, but rotten and partly germinated seeds comprised 21 percent of the failures. About 42 percent of the seeds were gone from unknown causes. Rodents undoubtedly removed some of these, and evidence indicated others were floated away by runoff from winter rains.

Survival and Mortality

After two growing seasons, established seedlings (fig. 2) were present in a third of the spots that received either one or two seeds each (table 2), a decrease of 22.9 percent from initial stocking. In contrast, nearly 60 percent of the spots in which two seeds were sown contained established seedlings, a decrease of only 16 percent

from initial stocking. Survival was better in lines 3 and 4 (two seeds), where 73.6 percent of the initial seedlings survived compared with 58.9 percent for lines 1 and 2 (one and two seeds). Both germination and survival data indicate that conditions for success were somewhat more favorable in the center of the unit.

Table 3.--Germination failure by cause, in 79 seedspots with two seeds each

Cause of failure	Seeds in staked spots				Proportion of total seeds failed
	Line 3	Line 4	Line 5	Total	
	Number				Percent
Removed by rodents					
Underground	23	14	11	48	30.4
Aboveground	2	2	2	6	3.8
Total	25	16	13	54	34.2
Hollow	2	1	2	5	3.2
Rotten	1	8	2	11	7.0
Arrested germination	5	1	16	22	13.9
Not found	17	26	23	66	41.7
Total	25	36	43	104	65.8
Total	50	52	56	158	100.0

Seedling mortality was relatively light. Only 34 percent of the initial seedlings died in the two-year period. Less than a sixth of the mortality occurred in the second year.

Almost two-thirds of first-year mortality was caused by cutting or chewing damage (table 4). This damage was caused by rodents, cutworms, other insects not identified, and unknown agents. Insects alone were responsible for more than one-third of deaths from all causes. Damage from insects was noted on newly germinated seedlings, and additional damage occurred throughout the growing season. Grasshoppers are believed responsible for most damage after midsummer. Injury was observed on all parts of the seedlings--roots,

stems, cotyledons, and terminal buds. Seedlings often faded gradually after being damaged; first-year mortality does not completely reflect the loss inflicted by insects during the first summer.

Mice and gophers were responsible for nearly 18 percent of the mortality. Most mouse damage was aboveground. All mouse damage occurred during germination, and over half of it occurred in line 5 (unbaited). Gophers damaged the seedlings underground, and their activities continued through the year.

Drouth, damping-off, trampling, drowning, and unidentified factors caused the remaining 38 percent of first-year mortality. Deaths from both drouth and drowning can be minimized by good seedspot selection. No deaths were ascribed to surface heat.

Seedling establishment in this study apparently indicates what is possible under average or better weather conditions. An

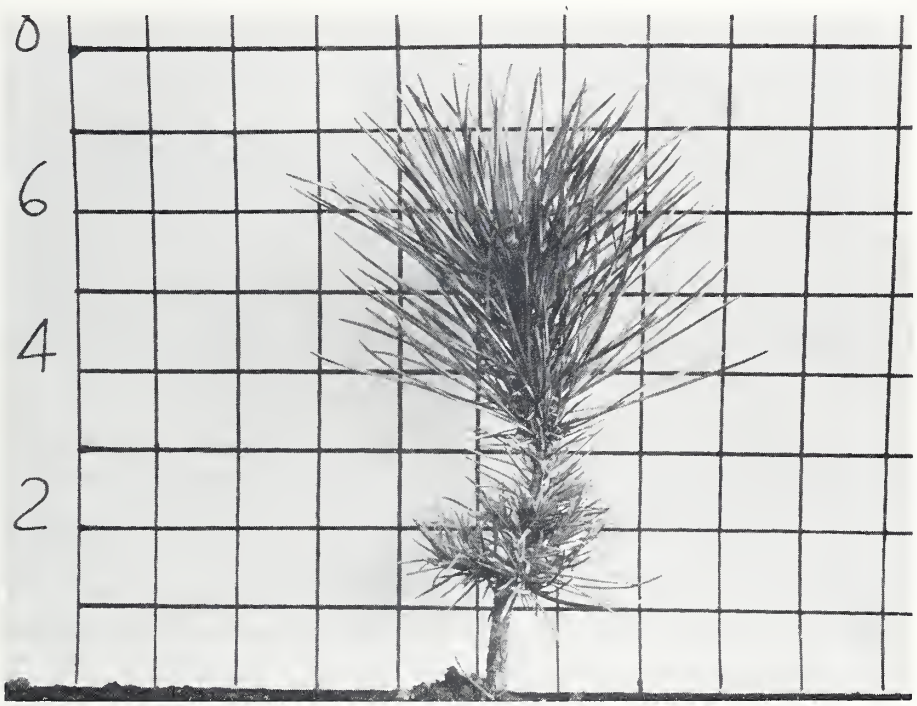

Figure 2.--A typical, sturdy, two-year-old sugar pine seedling almost 6" tall.

Table 4.--First-year seedling mortality

Mortality cause	Seedling deaths (by seedspot lines)						Proportion of total dead seedlings
	1	2	3	4	5	Total	
	Number						Percent
Seedlings cut or chewed							
Insects[1/]	15	5	11	4	18	53	35.8
Rodents	4	1	5	3	13	26	17.6
Cutworms	0	0	0	1	0	1	.7
Unknown	0	5	1	3	3	12	8.1
Total	19	11	17	11	34	92	62.2
Other causes							
Drouth	6	1	4	4	0	15	10.1
Damping-off	1	0	1	3	0	5	3.4
Trampling	0	0	0	0	1	1	.7
Drowning	0	0	0	0	1	1	.7
Unknown	6	8	4	7	9	34	22.9
Total	13	9	9	14	11	56	37.8
Total	32	20	26	25	45	148	100.0

1/ Unidentified.

inspection of weather records for the nearest weather station[3/] revealed that temperatures averaged 1.7 degrees below normal during the period April through September of 1953, and rainfall totaled 2.41 inches above normal in the same period. April, May, and June temperatures were particularly cool and it was the wettest May since 1942. However, April and July had slightly less than average

3/ U. S. Weather Bureau. Local climatological summary with comparative data. Roseburg, Oreg. 4 pp. 1951. Also, Roseburg climatological data for 1953 and 1954. Data recorded at Roseburg airport, approximately 33 airline miles from the seeding area and 2,500 feet lower in elevation.

rainfall. In 1954, temperatures again averaged below normal, but rainfall was 1.15 inches below average. It is likely that in seasons with exceptionally hot dry periods, somewhat more seedling losses can be expected from drouth and heat.

Stocking and Seedlings Per Acre

A quadrat survey was made at the end of the first and second growing seasons to determine distribution of sugar pine seedlings and the approximate number of stocked seedspots and seedlings per acre. Results of the survey, based on 4-milacre quadrats, were as follows:

Item	After first growing season		After second growing season	
	(Number)		(Number)	
Quadrats examined	101.00	--	105.00	--
Quadrats stocked	74.00	(73.3%)	76.00	(72.4%)
Seedspots stocked				
Average per quadrat	1.51	--	1.38	--
Average per acre	379.00		345.00	
Seedlings				
Average per seedspot	1.35		1.32	
Average per quadrat	2.04		1.82	
Average per acre	510.00		455.00	

The area now supports a well-stocked stand of sugar pine seedlings. Established seedlings were found on 73.3 and 72.4 percent of 4-milacre quadrats at the end of the first and second years, respectively. Although average number of seedlings on the area was reduced from 510 to 455 per acre by losses in the second season, stocking was hardly affected.

The seeding was entirely successful on the basis of the usual 4-milacre stocking criteria used in the Northwest. In the stocked quadrat method, 70-100 percent stocking is considered very satisfactory. Survey results indicate that our seeding efforts produced a satisfactory distribution of a sufficient number of trees. Thus, this first pilot-scale test has demonstrated that sugar pine regeneration

can be obtained by sowing seed in spots if the seed is adequately protected from seed-eating rodents.

SOME LEADS FOR IMPROVING SEEDSPOTTING

Satisfactory results in seedspotting can be achieved only by successful manipulation of a number of controllable factors that over-balance the effect of weather, soil, and other factors that are not readily controlled. Type of seedbed, time of seeding, rodent activity, and seeding method are some of the major controllable factors. As this pilot-scale seeding trial progressed, data collected on several of these factors indicated how seedspotting might be improved.

Type of Seedbed

Germination and survival are influenced by the character of the seedbed. These influences are illustrated by results in staked spots grouped into several classes of surface condition, seedbed composition, and vegetative cover.

Initial stocking, second-year stocking, and seedling survival were below average on ground that was undisturbed and unburned during logging and slash-burning (table 5). Seedlings appeared in only about half as many spots and survival totaled only 16.7 percent compared to the average of 58.9 percent. Both stocking and seedling survival were nearly average for areas that were disturbed in logging but remained unburned, and for those undisturbed areas where slash was burned (fig. 3). They were far above average for the small sample on skidroads.

Seedspots in all five staked lines were classified according to the composition of the seedbed surface that predominated within a 3-inch circle surrounding each spot. Although superficially similar, this classification is not comparable to the surface-condition classification. Furthermore, additional spots were included in this second classification. Therefore, it is reported separately.

Germination was poorer in the duff-litter seedbed than in other classes but survival was very satisfactory for all (table 6). In duff-litter, initial stocking was only 37.0 percent compared with an average for all classes of 66.7 percent. Almost two-thirds of the seedlings survived for the first two years and 68 percent of the spots initially stocked remained stocked. Seedling survival and second-

Table 5. --Influence of surface condition on germination and survival, two lines of staked seedspots

Surface condition	Spots sown	Spots stocked		2nd-year seedling survival[1/]
		Initially	2nd year	
	Number	Percent		
Undisturbed; unburned	28	32.1	7.1	16.7
Disturbed; unburned	75	60.0	33.3	59.3
Skidroad	6	100.0	83.3	77.8
Burned	92	57.6	38.0	63.4
Total	201	--	--	--
Average[2/]	--	56.2	33.3	58.9

1/ Total number of seedlings alive divided by total germinated.

2/ Weighted by spots sown.

Table 6. --Influence of seedbed composition on germination and survival

Seedbed Composition	Spots sown	Spots stocked		2nd-year seeding survival[1/]
		Initially	2nd year	
	Number	Percent		
Mineral soil	260	69.2	44.6	63.9
Wood-soil	175	66.8	45.7	65.5
Rock-soil	39	69.2	61.5	79.5
Duff-litter	27	37.0	25.9	64.3
Total	501	--	--	--
Average[2/]	--	66.7	45.3	65.7

1/ Total number of seedlings alive divided by total germinated.

2/ Weighted by spots sown.

Figure 3.--Typical burned surface condition. The ground is bare and blackened except for small vegetation that started growing the first season.

year stocking were substantially above average on the rock-soil seedbed.

The general stocking survey of the entire seeded area also revealed above-average stocking on rocky surfaces. This information is particularly gratifying because such areas have always been difficult to plant. Seedspotting promises to be a better method than any other for regenerating many shale-rock locations.

Initial stocking, second-year stocking, and seedling survival were poorest where vegetation was most dense (table 7). Two-thirds or more of the spots that were bare or had only a light cover were stocked initially, but only 54 percent of the spots with medium or heavy cover were stocked.[4/] Seedling survival was 68.6 percent

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4/ Cover density was rated ocularly at the end of the first year into four broad classes--none, light, medium, and heavy--on the basis of height and density of vegetation. Data for the medium and heavy classes were combined because there were only a few spots in each.

on bare ground, and only 55.6 percent in medium and heavy cover (fig. 4). These data definitely indicate that results are best where competing vegetation is least.

Table 7.--Influence of vegetative cover on germination and survival

Vegetative cover	Spots sown	Spots stocked		2nd-year seedling survival[1/]
		Initially	2nd year	
	Number	Percent		
None	332	66.3	47.6	68.6
Light	130	71.5	44.6	60.4
Medium & heavy	39	53.8	28.2	55.6
Total	501	--	--	--
Average[2/]	--	66.7	45.3	65.7

1/ Total number of seedlings alive divided by total germinated.

2/ Weighted by spots sown.

Examination of the several seedbed factors has brought out that germination and survival were better in those places where debris and vegetation had been eliminated. On the other hand, seed failure and seedling losses in staked spots were attributed mainly to rodents and insects and not to the common microsite factors of excessive heat and drouth. Although these facts appear to conflict, there is a logical and observed relationship. Mice are known to forage most intensively near debris where they are well protected from enemies. Gophers are most abundant in vegetated areas, and vegetation also provides the food and shelter necessary for the presence and build-up of large insect populations. The creation of a bare, vegetation-free seedbed accomplishes the two-fold purpose of providing a more suitable physical environment for the seedlings and a more unsuitable environment for rodents and insects.

Seeding Stratified Seed

Spring-sown sugar pine seedspots in the 2-acre spring trial were more heavily attacked by rodents than fall-sown spots that surrounded them. Largely because of rodent activity, seeds germinated in only 13 of 100 staked spots in which stratified seed were sown. This heavy rodent activity against spring-sown spots confirms observations in earlier studies.[5/]

The sugar pine seeds, stratified for 82 days, were surprisingly slow to germinate, and the seedlings made below-average height growth. Some seeds had already burst their seedcoats when sown on April 8; yet not a single seedling appeared aboveground within the following month. In contrast, seedlings from fall-sown seed first showed aboveground in early April and germination was one-fourth

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5/ Stein (see footnote 2).

Figure 4.--Vegetation and debris visible in the foreground typify conditions where germination and survival were below average

complete by May 5. First-year height growth of seedlings from fall-sown seed averaged 2.18 inches tall; from spring-sown, 1.80 inches. In dry years, late germination and slow growth may be a critical factor in seedling survival.

Present experience indicates that fall seeding of sugar pine is preferable to spring seeding.

Seedspot Spacing and Number of Seeds

The question of how many spots to sow to achieve a given spacing, and how many seeds to place in each spot must be resolved by a combination of biological and economic considerations. Cost of seedspotting is affected more by number of spots sown than by number of seeds sown in each spot. It would therefore be cheapest to sow a minimum number of spots and place enough seeds in each to assure that all would become stocked. However, to obtain the best type of stand, we desire to avoid a clump-wise distribution of trees. The best way to insure optimum distribution is to place only one seed in each spot and sow enough spots to assure that the desired number would become stocked.

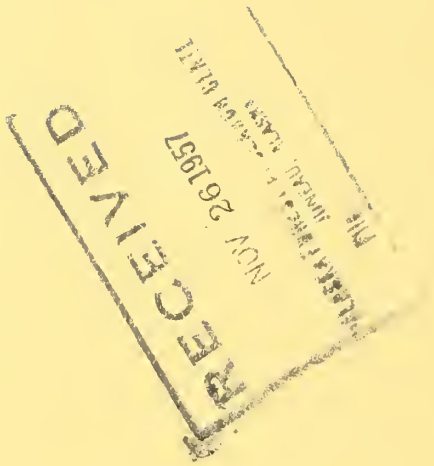
Data from this pilot-scale trial has been used to calculate an approximation of the seedspot-spacing and seeds-per-spot combination needed to achieve a second-year stand at 8 x 8 spacing. Staked spot results showed that nearly 30 percent of the high-quality seeds sown one and two at a time in alternate spots produced 2-year-old seedlings. In the limited area where two seeds were placed in every spot, the environment was better and 44 percent of all seeds produced seedlings. In the first instance each seed had 3 chances in 10 to produce an established seedling; in the second instance, 4.4 chances in 10. Using these two probabilities, the percentage of spots that should be stocked when a given number of seeds are sown in each spot was calculated and multiplied by the spacing desired (8 feet) to determine the required interval for placing spots within the row (table 8).

Because of environmental variations, however, each seed does not have an equal opportunity to make a seedling. If a spot is unfavorable for one seed it may be unfavorable for a dozen. Consequently, spots actually stocked totaled 82 percent of the calculated number where spots received alternately one and two seeds each, and 85 percent where spots received two seeds each. The calculated seedspot interval was reduced by the ratios from actual results to arrive at the best estimate for spacing seedspots within the row.

Table 8.--Combination of spacing within rows and seeds per spot necessary to get established seedlings equivalent to 8 x 8 spacing

Seeds per spot	Spots stocked			Required interval between spots	
	Calculated	Actual	Ratio 1/	Calculated	With adjustment
Number	Percent	Percent		Feet	Feet
	If 30% of the seeds produced seedlings				
1	30.0	--	--	2.4	2.0
1 & 2	40.5	33.3	0.82	3.2	2.7
2	51.0	--	--	4.1	3.4
3	65.7	--	--	5.3	4.3
4	76.0	--	--	6.1	5.0
	If 44% of the seeds produced seedlings				
1	44.0	--	--	3.5	3.0
1 & 2	56.3	--	--	4.5	3.8
2	68.6	58.5	0.85	5.5	4.7
3	82.4	--	--	6.6	5.6
4	90.2	--	--	7.2	6.2

1/ Actual/calculated.

If more than one seed is sown in each spot, many of the spots will still have only one established seedling. However, the proportion of spots that will end up with more than one seedling cannot be even approximated by the mathematics of probability. Where one and two seeds were alternated, 30 percent of the stocked spots contained two seedlings at the end of the second year, compared with 50 percent where two seeds were placed in every spot. The two seedlings are of nearly the same size in many spots but in many others one seedling is already dominant. Thus, a spacing of 4 x 8 feet between spots containing two seeds each appears reasonable from both the standpoint of cost and seedling development until faster seedspotting methods are devised or further observations indicate that such spots require thinning.

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